

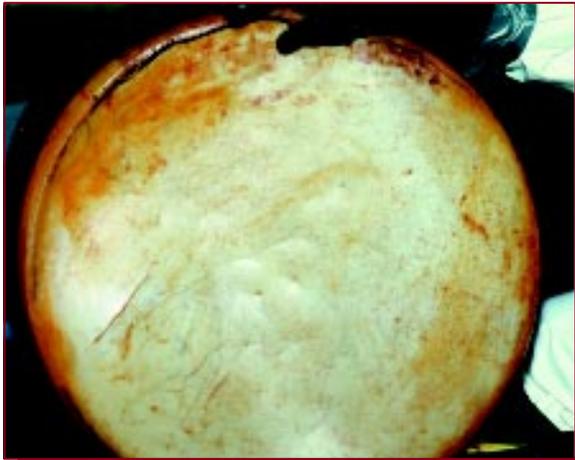
FINAL REPORT - NOVEMBER 1997



*Type B Accident
Investigation
Board
Report on the
Drum Explosion at
Building C-746-Q,
Paducah Gaseous
Diffusion Plant*

Oak Ridge Operations
U.S. Department of Energy





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INDEPENDENT REPORT

This report is an independent product of the Type B Accident Investigation Board (Board) appointed by James C. Hall, Manager, Oak Ridge Operations.

The Board was appointed to perform a Type B Investigation of this accident and to prepare an investigation report in accordance with U.S. Department of Energy Order 225.1, "Accident Investigations."

The discussion of facts, as determined by the Board, and the views expressed in the report do not assume and are not intended to establish the existence of any duty at law on the part of the U.S. Government, its employees or agents, contractors, their employees or agents, or subcontractors at any tier, or any other party.

This report neither determines nor implies liability.



RELEASE AUTHORIZATION



On September 17, 1997, I established a Type B Accident Investigation Board (Board) to investigate the drum explosion that resulted in the spill of hazardous/radioactive waste (mixed waste) within Building C-746-Q located at the Paducah Gaseous Diffusion Plant. The Board's responsibilities have been completed with respect to this investigation. The analysis process; identification of direct, contributing, and root causes; and development of judgments of need during the investigation were done in accordance with U.S. Department of Energy Order 225.1, "Accident Investigations." I accept the findings of the Board and authorize the release of this report for general distribution.

James C. Hall
Manager
Oak Ridge Operations



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LIST OF ABBREVIATIONS, ACRONYMS, AND INITIALISMS

AMEF	Assistant Manager for Enrichment Facilities
AMEM	Assistant Manager for Environmental Management
CFR	<i>Code of Federal Regulations</i>
DOE	U.S. Department of Energy
ERD	Environmental Restoration Division
ERT	Emergency Response Team
ESAMS	Energy Systems Action Management System
ETTP	East Tennessee Technology Park
HAZMAT	hazardous material
HAZWOPER	Hazardous Waste Operations and Emergency Response
L	liter
LMES	Lockheed Martin Energy Systems, Inc.
LMUS	Lockheed Martin Utility Services, Inc.
M	molar concentration
ORO	Oak Ridge Operations
ORPS	Occurrence Reporting and Processing System
OSHA	Occupational Safety and Health Administration
PCB	polychlorinated biphenyl
PGDP	Paducah Gaseous Diffusion Plant
PORTS	Portsmouth Gaseous Diffusion Plant
PPE	personal protective equipment
PSS	Plant Shift Superintendent
RCRA	Resource Conservation and Recovery Act
RWP	radiological work permit
SME	Subject Matter Expert
TRU	transuranic
USEC	United States Enrichment Corporation

EXECUTIVE SUMMARY

Evidence of a drum explosion was discovered the morning of September 15, 1997.

INTRODUCTION

On September 15, 1997, two health physics technicians and two waste management operators discovered evidence of a drum explosion. This accident, involving a spill of hazardous/radioactive waste (mixed waste), occurred in Building C-746-Q at the Paducah Gaseous Diffusion Plant (PGDP), Paducah, Kentucky. On September 17, 1997, James Hall, Manager, Oak Ridge Operations (ORO) established a Type B Accident Investigation Board (Board) to investigate this accident in accordance with U.S. Department of Energy (DOE) Order 225.1, "Accident Investigations" (see *Appendix A*).

ACCIDENT DESCRIPTION

The accident was discovered at approximately 9:40 a.m. on Monday, September 15, 1997, by two health physics technicians and two waste management operators in Section B of Building C-746-Q. Building C-746-Q is a Resource Conservation and Recovery Act (RCRA) permitted mixed waste storage facility. The building was immediately evacuated, the Plant Shift Superintendent (PSS) was notified, and the Emergency Response Team (ERT) was activated. The initial information relayed to the PSS at 9:57 a.m. from Building C-746-Q was that a drum located in Section B had fallen off a pallet into an aisle and spilled its contents. The Assistant PSS and the ERT arrived at the scene at 10:05 a.m. The ERT located a drum lying on its side (an 85-gal steel drum) and overpacked it in a 110-gal, polyethylene-lined, steel drum. The ERT noticed a large amount of dark brown liquid spilled in and around the dike of acid waste storage area B-08. Later, the ERT reentered the building to videotape the accident scene. During this entry, the



Exhibit ES-1. Components of HC-1093.

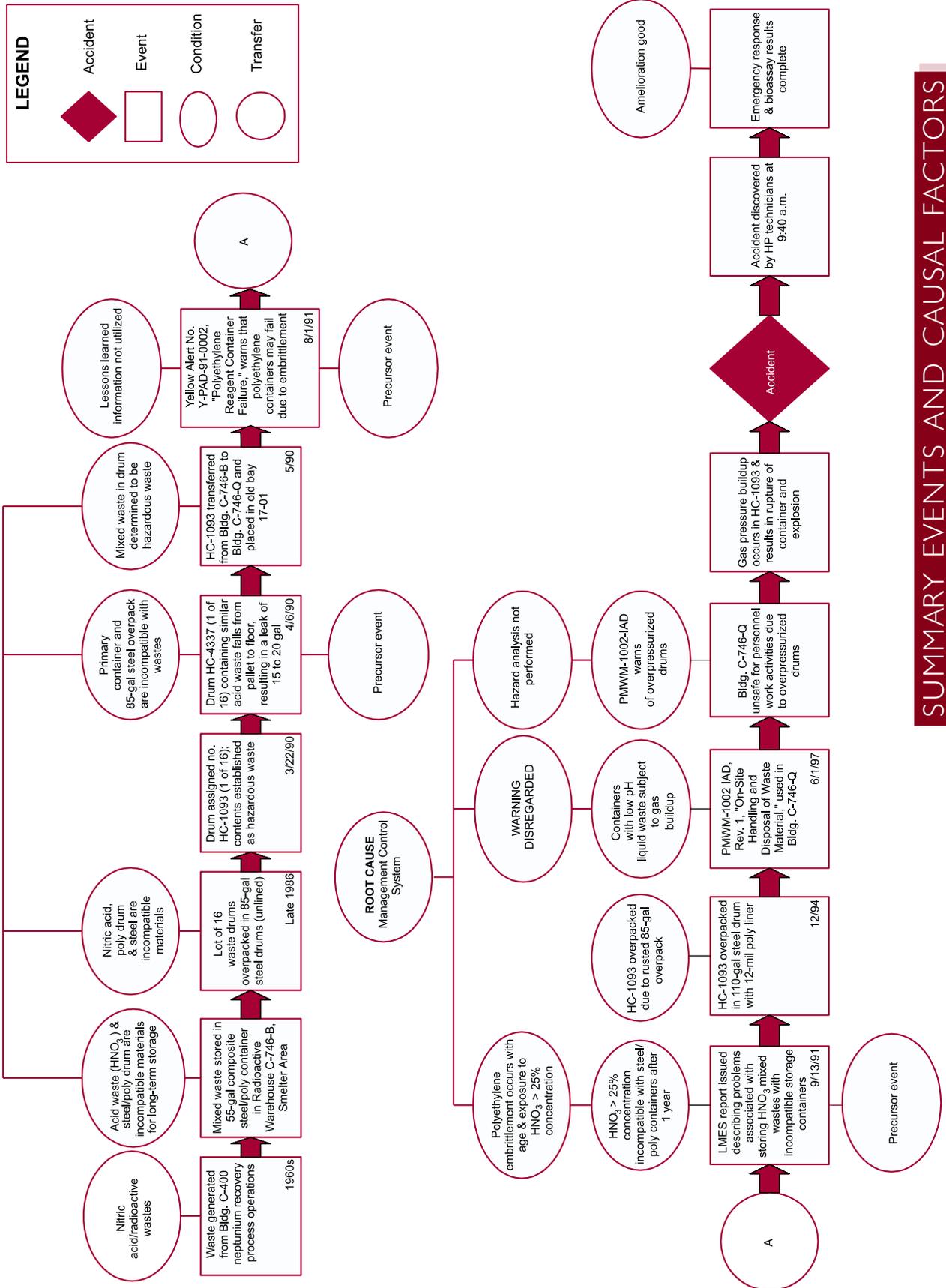
ERT discovered an open 110-gal, polyethylene-lined, steel drum (HC-1093) without a lid. Further investigation identified a 55-gal composite steel/polyethylene drum inside HC-1093. (Note: Although not known at this time, additional information discovered later revealed that the accident in-

The accident involved three drums overpacked in one configuration.

involved three drums in one configuration. Prior to the explosion, the container configuration consisted of a 55-gal composite steel/polyethylene drum overpacked in an 85-gal steel drum that was overpacked in a 110-gal, polyethylene-lined, steel drum. The 85-gal steel drum was ejected from the configuration due to overpressurization. *Exhibit ES-1* shows the components of HC-1093) The dark brown liquid in and around the diked area of acid waste storage area B-08 was now foaming. The building was sealed off, with work limited to stabilizing the accident scene.

CAUSAL FACTORS

Figure ES-1 depicts the logical sequence of events and causal factors for the accident. It indicates, in a time-sequenced flow, factors that allowed the accident to occur.



SUMMARY EVENTS AND CAUSAL FACTORS

Figure ES-1. Summary Events and Causal Factors Chart

The **direct cause** of the accident was the excessive buildup of pressure due to chemical reactions within the container, resulting in an explosion of the container. However, there were also **contributing causes** (causes that, if corrected, would not by themselves have prevented the accident but are important enough to be recognized as needing corrective action) and a **root cause** (a fundamen-



Management failed to recognize the significance of previous incidents.

tal cause that, if corrected, would prevent recurrence of this and similar occurrences). Causal factors are identified in *Table ES-1*, with a short discussion of each cause.

Table ES-1. Causal Factor Analysis

Causal Factor Analysis	
Contributing Causes	Discussion
Procedures	Warnings in existing procedures regarding the potential for gas buildup in waste containers were not heeded.
Waste acceptance criteria	There was no approved waste acceptance criteria document. The waste acceptance criteria did not place restrictions on the acceptance of strong oxidizers or address the limitation of polyethylene for long-term storage of strong oxidizers.
Overpack policy or practice	Policies and practices failed to provide guidance on when it is appropriate to repackage as opposed to overpacking a suspect container.
Occurrence reports	Occurrence reports do not always identify the appropriate root causes in past events. There is no single organization or individual responsible for tracking or trending information from the occurrence reporting system.
Lessons learned	There was a failure to properly implement the Lessons Learned Program, and the findings and recommendations in a Lockheed Martin Energy Systems, Inc. (LMES) report (<i>Proposed Neutralization/Pre-treatment for Nitric Acid Strip Tank Waste and Other Drummed Lab Wastes Stored in the Vault 4A Facility</i> , dated September 13, 1991) and a yellow alert (Y-PAD-91-0002, "Polyethylene Reagent Container Failure") were disregarded. There is no single organization or individual responsible for tracking or trending information from the lessons learned system.
Personnel safety	There was a failure to provide hazard analysis and mitigation for exploding drums for hazardous waste operations personnel working in Building C-746-Q (i.e., there was no safety and health plan). A required safety and health plan, including safety and health permits, must conform to Title 29 of the <i>Code of Federal Regulations</i> (CFR), Part 1910.120, "Hazardous Waste Operations and Emergency Response" (HAZWOPER).
DOE oversight	DOE failed to perform adequate oversight of environmental and waste management activities at PGDP and did not identify hazards from exploding waste drums.
Root Cause	Discussion
Failure of management control systems	LMES management failed to recognize the significance of and/or act appropriately on information regarding the incompatibility between acid wastes and waste containers.

CONCLUSIONS AND JUDGMENTS OF NEED

Based on its investigation and analyses of the resulting findings, the Board determined the conclusions and judgments of need delineated in *Table ES-2*.



Neither DOE nor LMES adequately trends information from occurrence reports or lessons learned.

Table ES-2. Conclusions and Judgments of Need

Conclusions and Judgments of Need

Conclusions

Judgments of Need

LMES has lessons learned procedures that could have, if adequately implemented, prevented this accident.

LMES management needs to:

- Adequately implement a Lessons Learned Program.
- Assess the criteria for assigning alert levels.
- Ensure the accuracy of occurrence reports and ensure the appropriate root cause(s) have been identified.

No documentation exists restricting the storage of strong oxidizing agents.

LMES needs to proceduralize a process for neutralizing corrosive wastes prior to long-term storage. Restrictions need to be placed on the acceptance of wastes that pose unique hazards when stored. The Waste Management Division needs to modify waste acceptance criteria (KY/EM-96) accordingly for treatment, storage, and disposal units.

PGDP container management procedures fail to provide guidance for repackaging wastes as opposed to overpacking.

LMES needs to:

- Develop guidance to repackage waste as opposed to overpacking the container when appropriate.
- Modify the waste handling procedure (PMWM-1002 IAD) to clarify the limitations of polyethylene-lined containers for storage of strong oxidizing agents.

There are no provisions for personnel safety from exploding drums in Building C-746-Q.

LMES needs to develop a safety and health plan for HAZWOPER personnel in Building C-746-Q that conforms to 29 CFR 1910.120 (HAZWOPER).

Neither DOE nor LMES adequately trends information from occurrence reports or lessons learned.

DOE needs to track and trend information from the occurrence reporting and lessons learned systems, as defined in ORO M 110, Change 2, dated May 15, 1997.

LMES needs to track and trend information from the occurrence reporting and lessons learned systems.

DOE does not perform adequate oversight.

DOE needs to:

- Develop a comprehensive assessment program for PGDP.
- Ensure occurrence report information is accurate and complete.

TYPE B ACCIDENT INVESTIGATION BOARD REPORT ON THE DRUM EXPLOSION AT BUILDING C-746-Q, PADUCAH GASEOUS DIFFUSION PLANT

1.0 INTRODUCTION

On the morning of September 15, 1997, two health physics technicians and two waste management operators discovered a spill in Section B of Building C-746-Q at the Paducah Gaseous Diffusion Plant (PGDP). The technicians immediately evacuated Building C-746-Q and notified the Building Supervisor. The Building Supervisor notified the Plant Shift Superintendent (PSS) of the accident at 9:57 a.m. The first report to the PSS was that a spill had occurred from a drum that had fallen off a pallet and into an aisle. Later that afternoon, a determination was made that a drum explosion had occurred with a resulting spill of hazardous/radioactive waste (mixed waste).

On September 17, 1997, James Hall, Manager, Oak Ridge Operations (ORO) established a Type B Accident Investigation Board (Board) to investigate this accident in accordance with U.S. Department of Energy (DOE) Order 225.1, "Accident Investigations" (see *Appendix A*).

Building C-746-Q is a single-story, metal-frame building with dimensions of 272 ft x 178 ft that is situated on a fully diked concrete slab.

1.1 FACILITY DESCRIPTION

Contractor activities regarding legacy and/or remediation wastes are managed by the local DOE Paducah Site Office with support from DOE-ORO, which is located in Oak Ridge, Tennessee. The facility in which this accident occurred is under programmatic direction of the DOE-ORO Office of Environmental Management.

On July 1, 1993, the United States Enrichment Corporation (USEC) began managing all uranium enrichment operations at PGDP. Lockheed Martin

Utility Services, Inc. (LMUS) is the operating contractor for these activities. In the Lease Agreement between DOE and USEC, DOE retains the responsibility for managing legacy wastes as well as all wastes generated as a result of environmental management and remediation activities conducted at PGDP. The lease also provides for DOE storage of some USEC-generated mixed waste. Lockheed Martin Energy Systems, Inc. (LMES) is the managing and operating contractor for these activities.

Building C-746-Q is a waste storage facility where the management, surveillance, storage, and monitoring of wastes occur. Building C-746-Q is a single-story, metal-frame building with dimensions of 272 ft × 178 ft that is situated on a fully diked concrete slab.

Building C-746-Q was classified as Nuclear Hazard Category 2 facility.

Exhibit 1-1 shows the exterior of Building C-746-Q. The building is shared between LMES (western portion) and LMUS (eastern portion, leased from DOE) and is separated by a floor-to-ceiling wall with two 6-in. dike risers at each rollup door. The inner wall is of concrete block construction. The outer walls and roof of the entire building are comprised of metal siding. As shown in *Figure 1-1*, the western half of Building C-746-Q, where the accident occurred, is approximately 172 ft × 178 ft. This half of the building is used for storage of hazardous/radioactive wastes (mixed wastes), including those contaminated with polychlorinated biphenyls (PCBs). The building is a Resource Conservation and Recovery Act (RCRA) Part B permitted facility. DOE has classified the facility as Nuclear Hazard Category 2 due to the quantity of fissile material stored within the Fissile Storage Area. The waste storage areas of the building are organized into liquid and solid sections. The liquid waste storage areas (Section B) are diked with 6- to 8-in. curbs,



Exhibit I-1.
Exterior of Building C-746-Q.

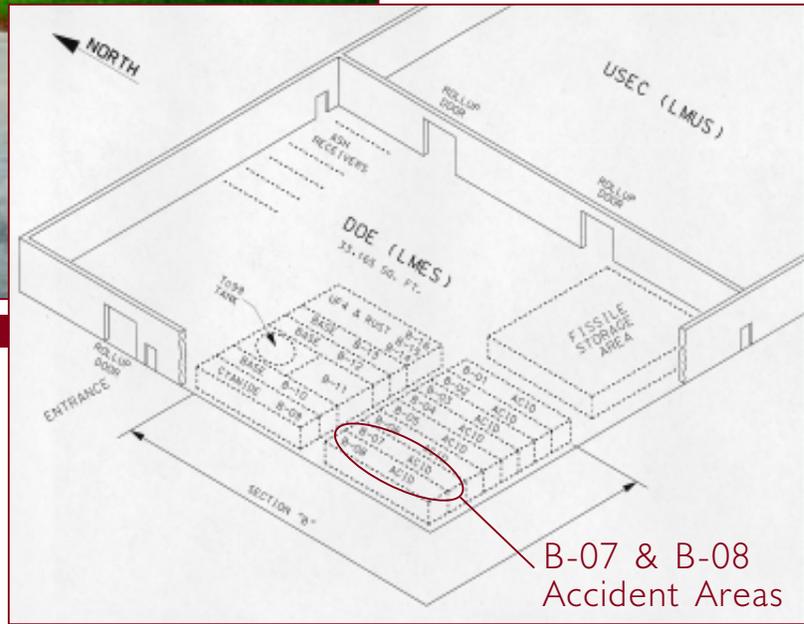


Figure I-1.
Layout of Building C-746-Q.

and ramps are provided for equipment access. There are 14 of these independently diked areas in the building. All diked areas contain palletized drums, with the exception of a 4,000-gal tank and the ash receivers.

1.2 SCOPE, PURPOSE, AND METHODOLOGY

The Board commenced the investigation on September 17, 1997, and submitted the findings to the Manager, ORO, on October 27, 1997.

The scope of the Board's investigation was to include, but not be limited to, analyzing causal factors and identifying root causes that resulted in the accident, and determining judgments of need to prevent recurrence. The Board conducted a walkthrough and reviewed photographs of the accident site, reviewed videotapes, reviewed events surrounding the accident, conducted extensive interviews and document reviews, and

performed analyses to determine the factors that contributed to the accident, including any management system deficiencies.

The purpose of this investigation was to determine the nature, extent, and causation of the accident and any programmatic impact, and to assist in the improvement of policies and practices, with emphasis on safety and waste management activities and systems. The Board focused on management roles and responsibilities; application of lessons learned from similar type accidents within DOE (especially those within LMES); and work planning, practices, and procedures. The Board used the following methodology:

- Facts relevant to the accident were gathered.
- Various analysis techniques, including event and causal factor charting, barrier and control analysis, change analysis, and causal factor analysis were used.

2.0 FACTS AND ANALYSIS

This section provides the facts and analysis of the accident. This section is written with facts as bullets and analysis as paragraphs.

2.1 ACCIDENT DESCRIPTION AND CHRONOLOGY

The following subsections provide the accident description, background of similar events, chronology of events, accident reconstruction and analysis, emergency response, personnel safety, and occurrence reporting.

2.1.1 Accident Description

The accident description information in this subsection was identified through the investigation process. The facts of the accident are presented as follows:

- The accident was discovered at approximately 9:40 a.m. on Monday, September 15, 1997, by two health physics technicians and two waste management operators in Section B of Building C-746-Q.
- The building was immediately evacuated, the PSS was notified, and the Emergency Response Team (ERT) was activated.
- The initial information relayed to the PSS at 9:57 a.m. was that a drum located in Building C-746-Q, Section B, had fallen off a pallet into an aisle and spilled its contents.
- The Assistant PSS and the ERT arrived at the scene at 10:05 a.m.
- The ERT donned Level A personal protective equipment (PPE), entered Building C-746-Q, and found a drum lying on the dike curb between acid waste storage areas B-07 and B-08.

Initial information reported to the PSS was incorrect.

- The ERT attempted to overpack this drum in an 85-gal overpack and were unsuccessful. They then requested a 110-gal overpack and placed the drum inside this 110-gal overpack. Before leaving the scene, the ERT noted a large amount



The 85-gal steel drum was ejected from the configuration due to overpressurization.

of dark brown liquid spilled in and around the dike of acid waste storage area B-08.

- Later in the afternoon, the ERT reentered Building C-746-Q in Level A PPE to videotape the scene to aid in further cleanup and assessment of the accident.
- During this entry, the ERT found a 110-gal, polyethylene-lined, steel drum (HC-1093) in its assigned position in acid waste storage area B-08 with the lid off. The lid was found lying approximately 10 ft away from HC-1093 within acid waste storage area B-08.
- Found inside HC-1093 was a 55-gal composite steel/polyethylene drum. (Note: Although not known at this time, additional information discovered later revealed the accident involved three drums in one configuration. Prior to the explosion, the configuration consisted of a 55-gal composite steel/polyethylene drum overpacked in an 85-gal steel drum that was overpacked in a 110-gal, polyethylene-lined, steel drum. The 85-gal steel drum was ejected from the configuration due to overpressurization.)
- The ERT noted that the dark brown liquid in and around the dike was now foaming.
- The building was sealed off, with work limited to stabilizing the accident scene.
- Chemical operators and health physicists reentered Building C-746-Q several times over the next 5 days to neutralize the spilled acid as well as the remaining acid in the drum. On several occasions, Draeger tubes were utilized to identify the types and levels of gases that were evolving from the neutralization reaction. The Draeger tubes indicated detectable levels of carbon dioxide, nitrogen dioxide, ammonia, and other byproducts.

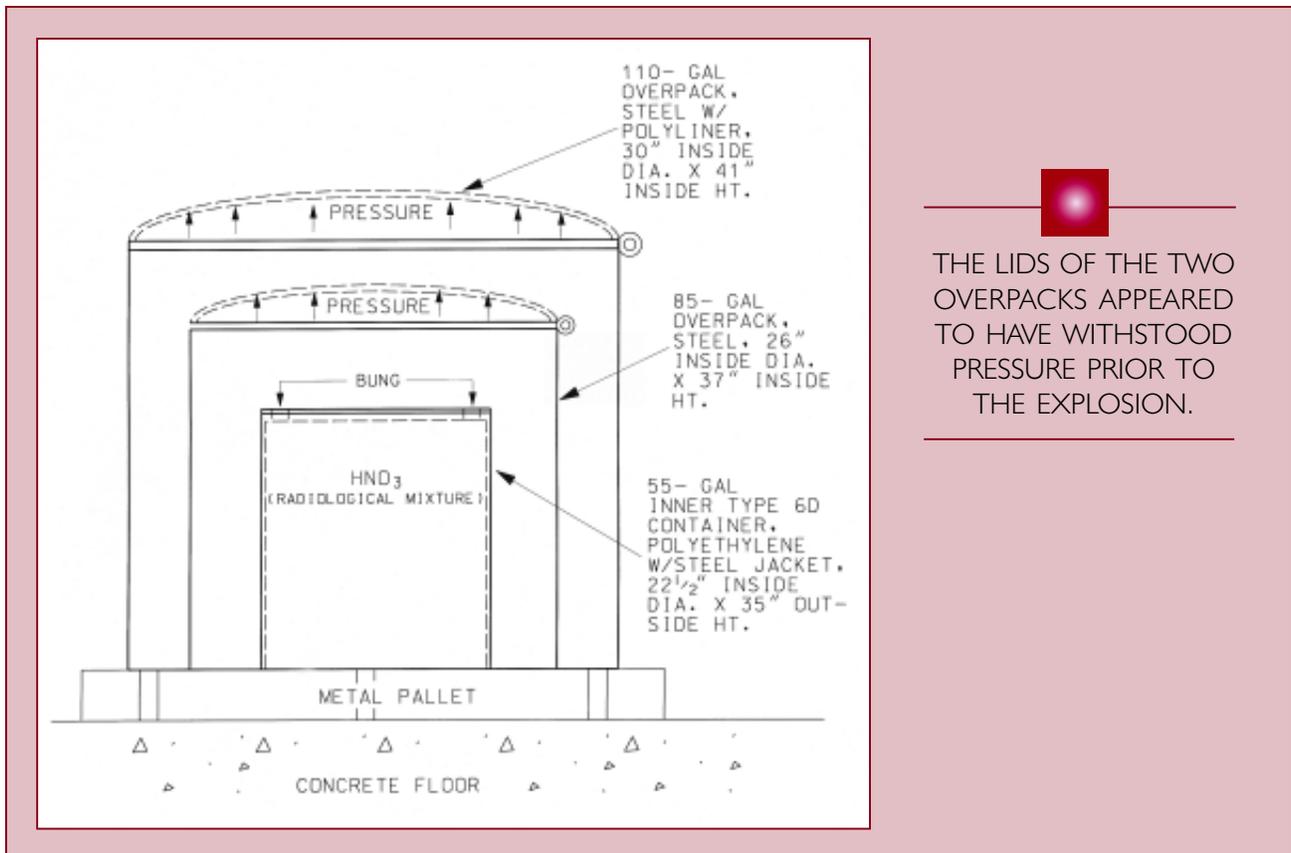
The original configuration of the drums prior to the explosion is shown in **Figure 2-1**. A description of each container is provided below and shown in **Exhibit 2-1**.

- 55-gal composite steel/polyethylene drum. The polyethylene drum was the innermost drum of the configuration. There were two bungs located on the top of the drum that were in place and tightly closed. The polyethylene drum was brittle. The drum contained a 12- to 15-in. horizontal breach approximately 1 in. from the top. On the bottom, a 24- to 26-in. breach near the side and a thin 10-in.-diameter area in the polyethylene were found. Within this thin area was one 4-in. breach. All that remained of the 55-gal steel drum surrounding the polyethylene drum was the lid, the ring, and approximately 14 to 16 in. of the area nearest the top. The remains of this steel drum were rusty, corroded, brittle, and thin.
- 85-gal steel drum (first overpack). This drum was the middle drum in the configuration. This drum was ejected from the configuration and found lying on its side approximately 15 ft away from its original location in an adjacent diked area. This drum contained a drum lid and ring in place on the drum. The drum lid was convex, giving

the appearance that it may have withstood pressure prior to the explosion. The bottom inch of the drum was missing, leaving an open container. The drum was rusty overall, with a rough and jagged bottom edge.

- 110-gal steel, polyethylene-lined drum (second and outer overpack). This drum was the outermost drum in the configuration. This drum was found with the drum ring in place on the drum, but the drum lid had been blown off. The drum lid was found approximately 10 ft away on the floor within the diked area (B-08). The drum lid was uniformly convex, giving the appearance that it may have withstood pressure prior to being blown off the drum. The bottom of the drum was also convex, giving the appearance that it may have withstood pressure prior to the explosion. There were three holes in the bottom of this drum believed to have been caused by acid corrosion after the event. No holes or breaches were visible in the polyethylene liner; however, after the accident, acid material was leaking from this drum.

Figure 2-1. Overpack Configuration Prior To Explosion.



THE LIDS OF THE TWO OVERPACKS APPEARED TO HAVE WITHSTOOD PRESSURE PRIOR TO THE EXPLOSION.

COMPONENTS OF HC-1093



Exhibit 2-1. Components of HC-1093.

2.1.2 Background of Similar Events

During the investigation, the Board discovered that several similar events preceded the accident discovered in Building C-746-Q. The following paragraphs detail the facts of those events.

- On March 22, 1990, at PGDP, acid waste drum HC-4337 was being transported from Building C-746-B to Building C-746-Q and fell 1 ft from a wooden pallet to the floor of Building C-746-Q. The primary container held low pH hazardous waste and was overpacked in a steel drum. The primary container was lined, but its lid was not lined and was not made of a material compatible with the low pH waste. The lid was badly deteriorated and leaked

approximately 1 gal of waste onto the concrete floor and into the steel overpack. Approximately 2 hours after drum HC-4337 was uprighted, a 1-in. hole in the bottom of the steel overpack resulted in a 15- to 20-gal spill.

A past corrective action was to place the remaining drums that were known to be incompatible with their overpacks into compatible storage containers.

An unusual occurrence report, UOR PGDP-90-2-C-746-Q-1, identified the use of incompatible containers as the cause of the incident. A corrective action plan was prepared, and one

of the recommended corrective actions was to “place remaining drums that are known to be incompatible with their overpacks into compatible storage containers.”

- On June 5, 1991, at the PGDP Laboratory, Building C-720, a 1-liter (L) polyethylene bottle, which contained, in part, concentrated nitric acid, shattered, spilled its contents, and injured an employee. The event was noted in a yellow alert (Yellow Alert No. Y-PAD-91-0002, “Polyethylene Reagent Container Failure”) that strong oxidizing agents are likely to cause embrittlement and subsequent failure of polyethylene containers. No written response was required for this yellow alert.
- On July 22, 1991, at the K-25 Site, which is now known as East Tennessee Technology Park (ETTP), one of four drums containing nitric acid stripping waste generated at ETTP failed and released its contents. The drum that failed had been overpacked in an unlined steel drum. A team was commissioned to investigate the incident, and its findings were issued on September 13, 1991, in an LMES report titled *Proposed Neutralization/Pre-treatment for Nitric Acid Strip Tank Waste and Other Drummed Lab Wastes Stored in the Vault 4A Facility*. This report provides specific recommendation g acid wastes that are similar to the acid wastes involved in the accident reported on Monday, September 15, 1997, in Building C-746-Q located at PGDP. There is no evidence that the report was shared with sites other than ETTP, although PGDP and the Portsmouth Gaseous Diffusion Plant (PORTS) had similar operations.
- As recently as July 2, 1997, a Y-12 Plant yellow alert (Yellow Alert No. Y-1997-OR-LMESY12-0701, “Nitric Acid Causes Drum Over-Pressurization”) was issued. The yellow alert identified the mixing of nitric acid waste with organic material as the cause. However, the root cause of the accident was a failed polyethylene-lined container caused by nitric acid. No written response was required for this yellow alert.

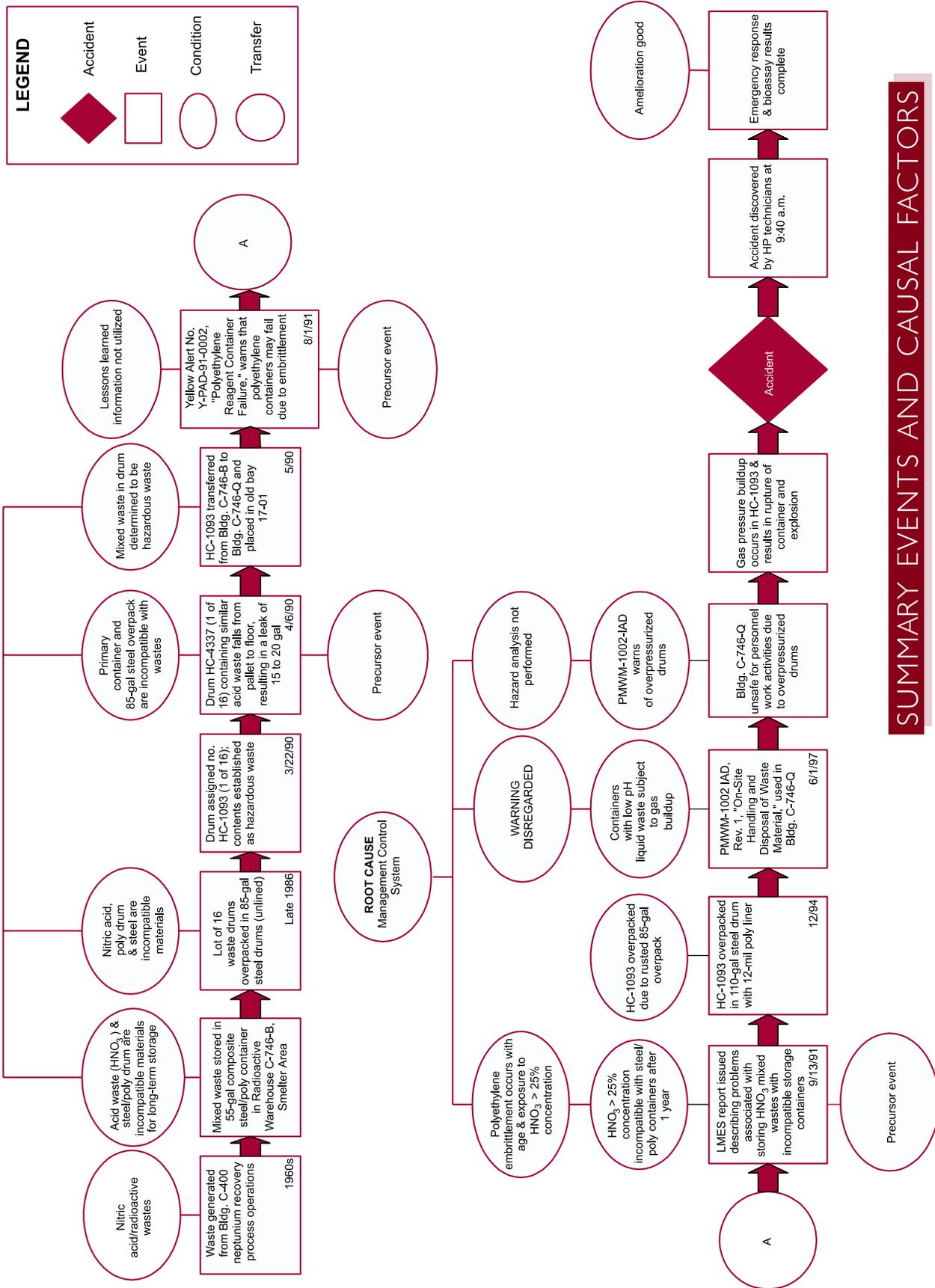
2.1.3 Chronology of Events

Following are the facts of the events that led to the accident discovered on September 15, 1997, in Building C-746-Q at PGDP. *Figure 2-2* summarizes the chronology of significant events and associated causal factors.



The integrity of the inner polyethylene/steel container had been questioned several times beginning in 1983.

- The container that exploded (HC-1093) contained nitric acid/radioactive mixed waste that was generated in the 1960s as a result of nickel stripping activities in the Building C-400 neptunium recovery process. The wastes from the recovery process were stored in 55-gal composite steel/polyethylene containers in Radioactive Warehouse C-746-B, Smelter Area.
- In a PGDP letter and report, dated September 26, 1983, titled *Drums in C-746-B Radioactive Warehouse*, a recommendation was issued for managing the “lot” of nitric acid/radioactive wastes. This document provided the details of an extensive study of the waste in the drums. A recommendation was made to treat and repack this waste due to the potential failure of the drums. The letter stated that the drums containing the wastes were of poor quality and should be replaced.
- From the meeting minutes titled “Meeting on PGDP TRU Waste,” dated July 23, 1984, questions were again raised about the reliability of the nitric acid/radioactive waste drums during their proposed transfer from Building C-746-B to Building C-400 for solidification. It was noted that the inner plastic liner could fail during transfer.
- Due to concerns with the drum’s integrity, HC-1093 was overpacked in an 85-gal steel drum in late 1986. The 85-gal steel overpack did not contain a polyethylene liner.



SUMMARY EVENTS AND CAUSAL FACTORS

Figure ES-1. Summary Events and Causal Factors Chart.

-
- On January 16, 1990, an attempt was made to sample and analyze HC-1093 for radioactive and RCRA constituents. The sample technician was unable to loosen the bung; therefore, the sample was not obtained until January 25, 1990. A pH of 1 was not determined until March 21, 1990.
 - In May 1990, HC-1093 was transferred from Building C-746-B to Building C-746-Q when it was determined to contain RCRA hazardous waste. HC-1093 was placed in old bay 17-01 and later moved to old bay C-03.
 - In December 1994, HC-1093 was placed in a 110-gal, polyethylene-lined, steel overpack. This was done in accordance with the corrective action plan resulting from the April 6, 1990, unusual occurrence report (UOR PGDP-90-2-C-746-Q-1).
 - In May 1997, HC-1093 was moved from old bay C-03 to acid waste storage area B-08 following completion of floor repairs in B-08 (Section B).
 - On July 28, 1997, HC-1093 and other waste containers were analyzed for pH. One of the other waste containers was HC-385. HC-385 was located on the same pallet as HC-1093. HC-385 was removed from acid waste storage area B-08 when pH analysis showed its contents to be caustic. To accomplish the relocation of HC-385, the entire pallet (which also held HC-1093) was removed from B-08. Later in the same day the pallet, containing HC-1093 but not HC-385, was returned to B-08.
 - On Friday, September 12, 1997, a RCRA inspection was performed. All storage locations within Building C-746-Q were inspected in accordance with RCRA permit requirements. Inspection requirements include, but are not limited to, container condition, appearance, etc. All drums were found to be acceptable.
 - On September 15, 1997, two health physics technicians and two waste management operators observed a drum lying on the dike

curb between acid waste storage areas B-07 and B-08 in Building C-746-Q. The building was evacuated immediately pending emergency response actions.

2.1.4 Accident Reconstruction and Analysis

The accident was not observed by anyone when it occurred; therefore, many of the accident reconstruction statements were based upon the Board's technical judgment, experience, and analysis of the best available information. The best available information consisted of sampling and laboratory data, extensive personnel interviews, pictures of the accident site, and visual inspection of the accident site and materials.



A RCRA inspection of the drums within Building C-146-Q was conducted on Friday, September 12, 1997.

- The accident involved three drums in one configuration. Prior to the explosion, the configuration consisted of a 55-gal composite steel/polyethylene drum overpacked in an 85-gal steel drum that was overpacked in a 110-gal, polyethylene-lined, steel drum. The 85-gal steel drum was ejected from the configuration due to overpressurization.
- The 55-gal composite steel/polyethylene drum (innermost container in the configuration) had been in use for approximately 35 to 40 years. This drum was used to contain waste from the nitric acid stripping activities conducted within Building C-400. The waste is concentrated with greater than 70% (pH of 0 or 1) nitric acid.
- An LMES daily RCRA inspection of the drums within Building C-746-Q was conducted from 10:10 a.m. to 11:00 a.m. on Friday, September 12, 1997, and the building was locked at the end of the day. No personnel entered the building until 6:05 a.m. on Monday, September 15, 1997.

-
- The accident was discovered at 9:40 a.m. on Monday, September 15, 1997. Personnel conducted routine work activities away from the accident location within Building C-746-Q from 6:05 a.m. until the accident was discovered at 9:40 a.m..
 - The accident occurred in the southwest corner (Section B) of Building C-746-Q as shown in **Figure 2-3**. A 110-gal, polyethylene-lined, steel drum (HC-1093) containing a nitric acid/radioactive waste mixture exploded, scattering some of its contents over an inside area (Section B) of the building covering approximately 400 ft². The nearest wall (west side) as well as the ceiling immediately above the drum had been splattered with the contents of the drum. Most of the liquid from the drum was contained within the diked area (B-08), and the liquid collected/drained to one corner.
 - The explosion did not displace the outer drum (HC-1093) from its original location. HC-1093 was found with the drum ring in place on the drum, but the drum lid had been blown off. The drum lid was found approximately 10 ft away on the floor within the diked area (B-08). The drum lid was uniformly convex, giving the appearance that it may have withstood pressure prior to being blown off the drum.
 - A 55-gal composite steel/polyethylene drum, containing two bungs in the top, was found inside HC-1093.
 - An 85-gal steel drum was ejected from HC-1093, hit the ceiling of Building C-746-Q, and landed approximately 15 ft away from HC-1093. The 85-gal steel drum was lying on its side within an adjacent diked area (B-07) with its lid and ring in place on the drum. The drum lid was convex, giving the appearance that it may have withstood pressure prior to the explosion. The bottom inch of the 85-gal drum appeared to have been corroded by acid.
 - A steel drum lid and ring was found lying adjacent to the 85-gal steel drum. The steel drum lid and ring were originally thought to be the lid and ring of the 85-gal steel drum. Closer inspection of the steel drum lid and ring showed that the drum lid had two holes in it (bung holes) and that the ring fit the drum lid. Later, it was determined to be the lid and ring of the 55-gal composite steel/polyethylene drum.
-
- The concentrated nitric acid stored in contact with the polyethylene liner caused the polyethylene liner to become extremely brittle.**
-
- The paragraphs below present the analysis of the accident reconstruction facts.
- The concentrated nitric acid stored in contact with the polyethylene liner over an extended period (from approximately 1960 to 1997) caused the polyethylene liner to become extremely brittle. The concentrated nitric acid slowly seeped through the hairline fractures of the degraded polyethylene liner. During this time, the continual cycle of heating and cooling of the drum contents due to natural environmental conditions as well as the continual degradation of the polyethylene liner induced by the concentrated nitric acid caused “wicking” of minute quantities of escaped acid between the surfaces of the composite steel/polyethylene drum. In this case, wicking means the movement of liquids (condensation and concentrated nitric acid) along the outer walls of the polyethylene liner and the inner walls of the steel drum. The wicking of the concentrated nitric acid resulted in an extremely corroded, thin, and weak 55-gal steel drum. Over time, more and more hairline cracks developed in the polyethylene, weakening this liner.
- It can be seen in **Exhibit 2-2** that the polyethylene drum is very thin within a 10-in.-diameter bottom area. The 4-in. breach in the thin and brittle bottom of the polyethylene drum could have been

ACCIDENT LAYOUT

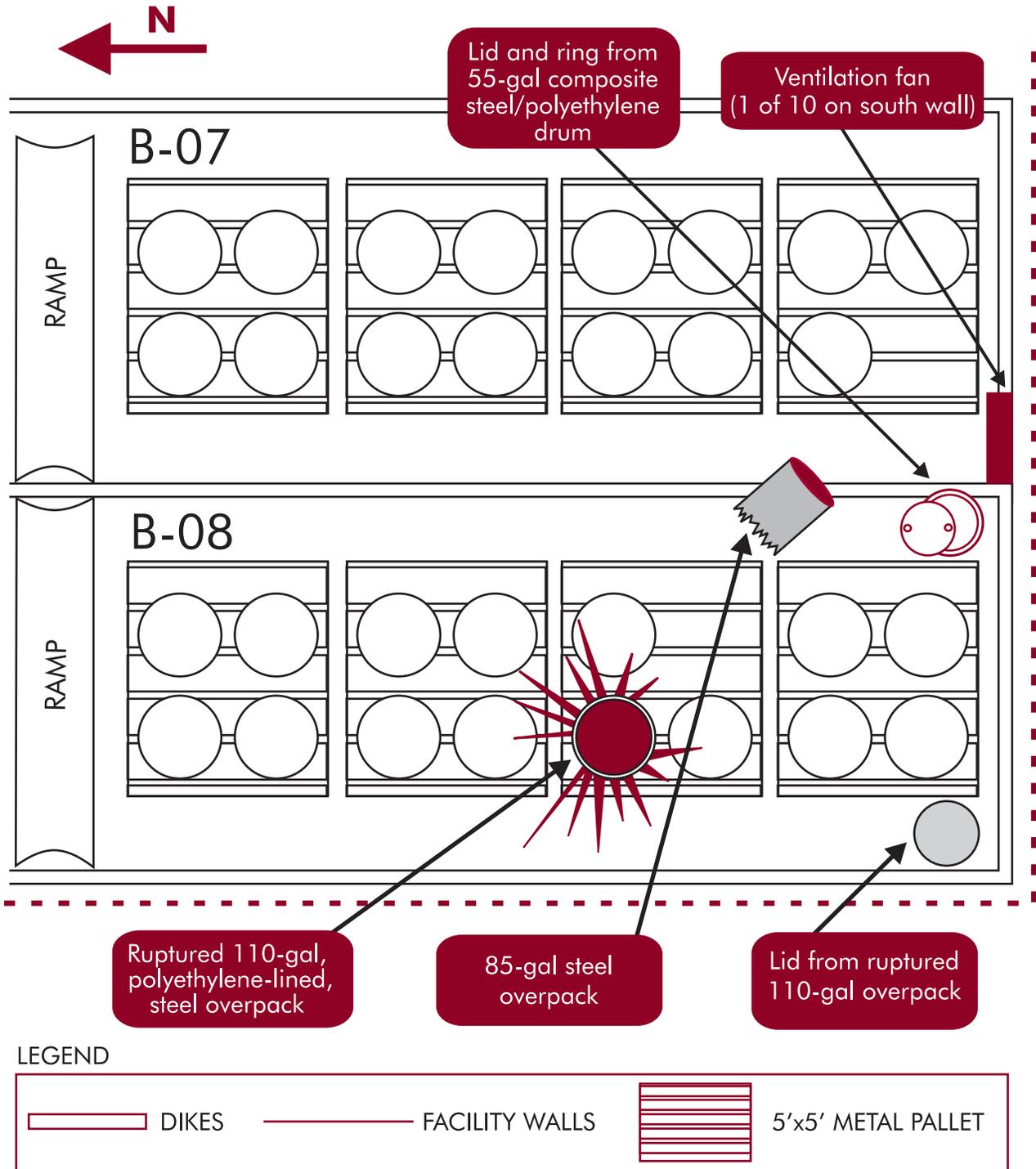


Figure 2-3. Accident Layout.

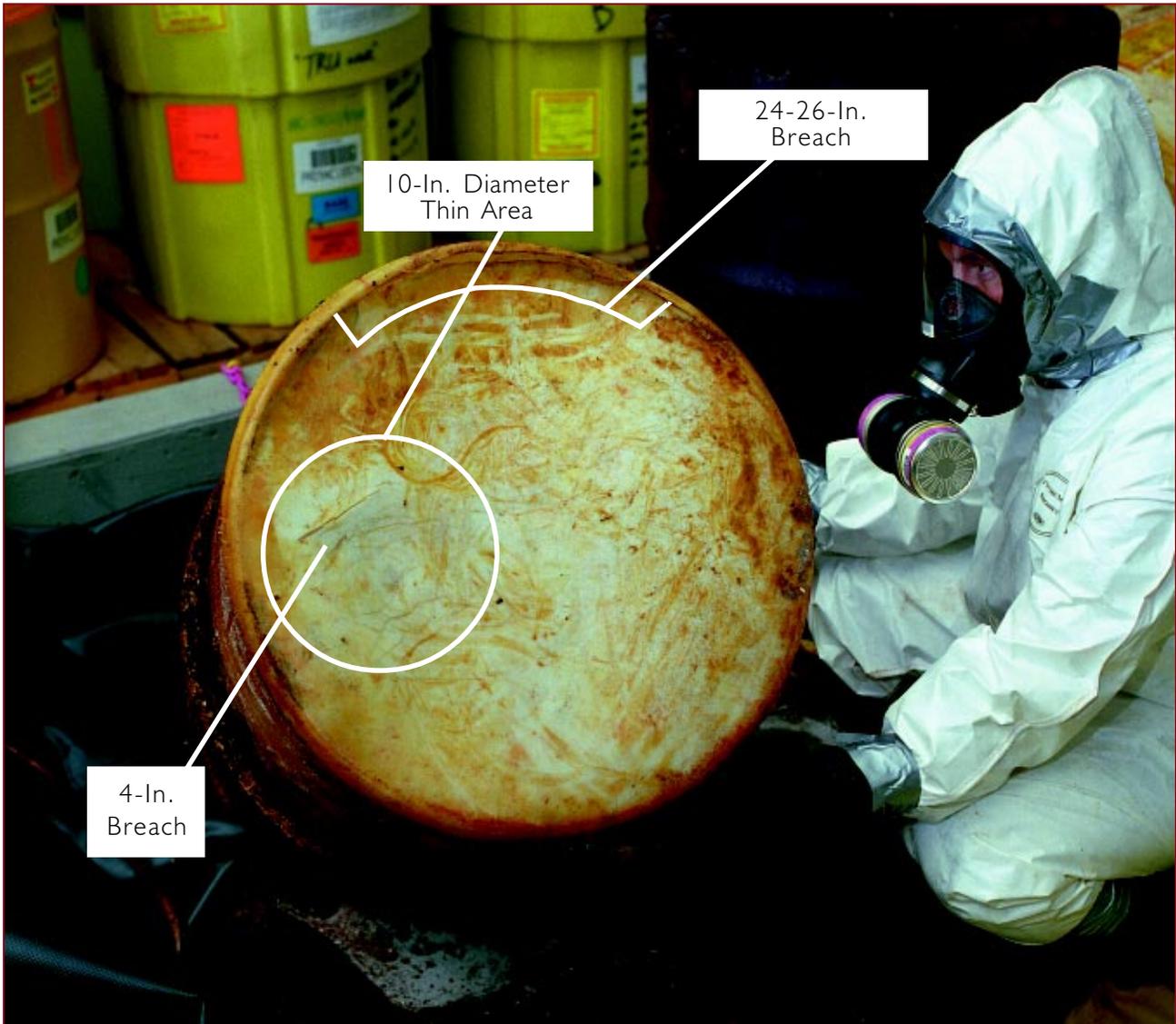


Exhibit 2-2. Bottom of 55-gal Polyethylene Drum.

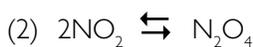
Nitric acid above concentrations of about 25% (250,000 mg/L) is a strong oxidizer with a history of unpredictably reactive incidents and a long list of incompatible materials.

caused by the sampling tool (caliwasa) during the sampling event on July 28, 1997. The sampling event and the subsequent movements of HC-1093 provided enough additional stress to the inner polyethylene liner to cause a breach large enough to allow acid to reach a greater surface area of the metal and intensify the acid/metal reaction. The

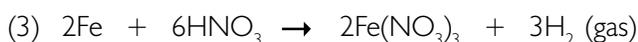
resulting gases produced from the intensified acid/metal reaction caused the overpressurization of the 85-gal steel overpack and HC-1093. Pressure initially built up within the 85-gal steel overpack from the acid attack on the inner metal surface of this container as well as the intense acid attack on the aged and extremely brittle 55-gal steel drum. The 55-gal steel drum provided very fine iron particles/powder that reacted with the concentrated nitric acid, causing a rapid buildup of gases.

Nitric acid above concentrations of about 25% (250,000 mg/L) is a strong oxidizer with a history of unpredictably reactive incidents and a long list of incompatible materials. Nitric acid must be

handled with great care because it is extremely corrosive and particularly reactive with organics (especially alcohols) and metal powders. Consideration should be given not only to the compatibility of materials with nitric acid, but to controlling rates of addition, concentration, temperature, agitation, order of addition, transfer routes, storage, and protection of operating personnel and equipment. The mechanism of nitric acid oxidation of iron, when the concentration is 7 molar concentration (M) or greater (about 400,000 mg/L as nitrate ion), proceeds according to the following set of chemical equations. These chemical equations show the probable reactions that took place within the 85-gal steel overpack.



It can be seen from equation (1) that 3 moles of gas (NO_2) are generated for every 1 mole of iron present; therefore, with the addition of an excess amount of acid, gas buildup is rapid. The mechanism of nitric acid oxidation of iron, when the concentration is between 1 and 2M (about 85,000 mg/L), proceeds according to the following chemical equation. This chemical reaction could also have taken place within the 85-gal steel overpack.



As the acid/metal reaction continued, the pressure within the 85-gal steel overpack increased rapidly. The acid/metal reaction continued primarily within the bottom of the 85-gal steel overpack and severely weakened the bottom and extreme lower (approximately 1 in.) portion of this drum. As the bottom of this drum became corroded by the reaction, small holes formed and allowed some of the gases to leak into the 110-gal, polyethylene-lined, steel overpack (HC-1093). This buildup of gases caused an overpressurization of HC-1093. The continuing rapid buildup of pressure inside the 85-gal steel overpack caused the explosion. The weak point of the 85-gal steel overpack was the bottom, where the majority of the acid/metal reaction occurred. The release of pressure was concentrated at the bottom of the 85-gal steel overpack, and the pressure forced the 85-gal steel overpack out



The acid/metal reaction caused a rapid buildup of pressure inside the 85-gal steel overpack, leading to the explosion.

of the top of HC-1093 with enough force to hit the ceiling of Building C-746-Q and be diverted towards an adjacent diked area (B-07) within the acid waste storage area. The lid of HC-1093 was also blown to the ceiling and landed 10 ft away from its original location.

2.1.5 Emergency Response

Response by site personnel from discovery of the accident to completion of emergency response activities consisted of the following facts.

- Site personnel were alerted by the health physics technicians and immediately evacuated Building C-746-Q.
- The Building Supervisor notified the PSS at 9:57 a.m. and requested assistance from the Fire Services Division and Chemical Operations Division. The Assistant PSS, Site Safety Officer, Incident Commander, and firefighter personnel responded to the accident scene.
- The Incident Commander established roadblocks to control traffic around Building C-746-Q and established the Incident Command Post in the C-333-A Cylinder Yard northwest of Building C-746-Q.
- Two firefighters (the ERT), dressed in Level A PPE, entered the accident area at 10:30 a.m. and overpacked the 85-gal steel drum in a 110-gal, polyethylene-lined, steel overpack. The firefighters reported a spill of brown liquid on the concrete floor. The Site Safety Officer established a decontamination line for the firefighters as they exited the building.
- The second entry into Building C-746-Q occurred at 1:00 p.m. and was performed by two firefighters (the ERT) who videotaped

the accident scene. The ERT reported that the brown liquid spill on the floor was producing a lighter colored, frothy foam. The ERT conducted air monitoring for nitric acid during this time. Of the three locations sampled only the area over the spill resulted in a detectable level of 3 ppm nitric acid. The Occupational Safety and Health Administration (OSHA) 8-hour time-weighted average limit is 2 ppm.

- Due to the potential for multiple chemical reactions, air samples were collected and analyzed to ensure personnel safety and appropriate PPE. This practice continued throughout the remaining response activities.



Level A PPE was utilized due to the unknown conditions.

- A Hazardous Material (HAZMAT) Team (chemical operators) was assembled and entered Building C-746-Q at 9:34 p.m. to spray the contaminated area and drums with a soda ash and water mixture. The HAZMAT Team exited the contaminated area at 10:00 p.m. to change air packs. The HAZMAT Team reentered Building C-746-Q at 10:15 p.m. and spread additional soda ash on the floor of the contaminated area. The HAZMAT Team exited the contaminated area at 10:30 p.m.
- Bioassay tests were performed on personnel present when the accident was discovered and on first responders to the accident (the ERT). Bioassay test results were negative for all personnel.

2.1.6 Personnel Safety

Following are facts concerning the safety of hazardous waste operations personnel working in Building C-746-Q.

- The Supervisor responsible for Building C-746-Q indicated that personnel are present within

the building approximately 80% of normal duty hours. The building is closed and locked each day at close of business. The building was unlocked at 6:05 a.m. on September 15, 1997, by a subcontractor chemical engineer and three environmental monitoring samplers. The chemical engineer and environmental monitoring samplers were the first personnel to enter Building C-746-Q. By the time of discovery of the accident at 9:40 a.m., approximately 16 people had been in the building. The personnel who had been in the building included the chemical engineer, six environmental monitoring samplers, four health physics technicians, one environmental monitoring sampler supervisor, two electricians, and two waste management operators.

- PMWM-1002 IAD, Rev. 1, "On-Site Handling and Disposal of Waste Materials," warns of gas pressure buildup in waste containers. Appendix O of this procedure addresses proper handling of potentially pressurized drums, including drums with low pH wastes, and the response of personnel who discover pressurized drums.



No safety and health work permit or safety and health plan relating to work in Building C-746-Q was in place at the time of the accident.

- Radiological work permit (RWP) 97-ER-003-G, utilized for tours, inspections, and minor hands on activities, and RWP 97-ER-004-G, utilized for minor maintenance and decontamination of areas and equipment, were in effect at the time of the accident. Both RWPs expire on December 31, 1997. These RWPs specify radiological surveys by health physicists for tools, equipment, and materials, and a body frisk for radioactive contamination after any work is performed in Building C-746-Q. No safety and health work permit or safety and health plan relating to work in Building C-746-Q was in place at the time of the accident.

- Title 29 of the *Code of Federal Regulations* (CFR), Part 1910.120, “Hazardous Waste Operations and Emergency Response” (HAZWOPER), requires the development and implementation of a written safety and health program for employees in hazardous waste operations. The program should be designed to identify, evaluate, and control safety and health hazards, and provide for emergency response for hazardous waste operations. The written safety and health plan must be supported by site procedures that implement provisions of the plan. CP2-EP-EP5031, Rev. 1, “Oil and Hazardous Materials Spills and Releases,” provides direction for responding to overpressurized (bulging) drums containing oil, hazardous materials, or hazardous waste.
- Daily RCRA inspections are performed in Building C-746-Q for aisle spacing; container stacking, condition, sealing, and labels; safety and emergency equipment; spill containment; general appearance; unacceptable material; security devices; and cylinder condition. A RCRA inspection was performed between 10:10 a.m. and 11:00 a.m. on September 12, 1997. All of the RCRA inspection items received an acceptable rating for the last working day prior to the accident. The inspection log did not indicate the presence of bulging drums.

The paragraphs below present the analysis of the safety of hazardous waste operations personnel working in Building C-746-Q.

Although PMWM-1002 IAD warns of overpressurization of containers, the procedure does not identify hazards to personnel involved in routine waste operations from overpressurized and/or exploding drums or means of mitigating these hazards.

The work activity sections of RWP 97-ER-003-G and RWP 97-ER-004-G did not take into account hazards from exploding/overpressurized drums and, subsequently, did not specify proper protective clothing and equipment for personnel working in the presence of these hazards. RWPs were not intended to protect personnel from hazardous waste (exploding drums, etc.) industrial accidents.

The Board found no evidence of a safety and health work permit or safety plan relating to personnel working in Building C-746-Q. A written, site-specific safety and health plan that identifies hazards and methods of mitigation is required by 29 CFR 1910.120 (HAZWOPER). CP2-EP-EP5031 provides direction for responding to overpressurized (bulging) drums containing oil, hazardous materials, or hazardous waste. However, hazards to fire services personnel attempting to puncture or open drums from explosions/overpressurization are not identified or mitigated.

2.1.7 Occurrence Reporting

Occurrence Report ORO-LMES-PGDPENVRES-1997-0008, *Waste Drum Rupture Inside Building C-746-Q RCRA Waste Storage Facility*, was reported at 9:57 a.m. and categorized as off-normal at 6:45 p.m. on Monday, September 15, 1997. The occurrence was classified as a cross-category item with potential concerns/issues. The incident category was later upgraded to an unusual occurrence upon consideration that Building C-746-Q was a Nuclear Hazard Category 2 facility. The occurrence was not categorized within the 2-hour time limit required by DOE Order 232.1.

2.2 MANAGEMENT SYSTEMS AND CONTROLS

The subsections to follow provide information on the management systems and controls utilized by LMES to conduct activities at PGDP.

2.2.1 Policies and Procedures

Facts pertaining to policies and procedures applied to this investigation are provided as follows:

- DOE Standard 7501-95 (DOE-STD-7501-95) provides guidance for implementing a Lessons Learned Program.
- A Lessons Learned Program existed on June 5, 1991, as evidenced by Yellow Alert No. Y-PAD-91-0002. The current LMES Lessons Learned Program is documented in Procedure QA-331.

- LMES Procedure QA-331 identifies criteria for issuing alerts. An appropriate alert level for an uncontained, on-site, hazardous release requiring cleanup is subjective and not well defined.
- LMES Procedure OP-301, "Occurrence Notification and Reporting," requires investigation and the establishment of the root cause for an accident.
- LMES Procedure PMWM-1002 IAD, "On-Site Handling and Disposal of Waste Materials," dated June 1, 1997, provides warnings of potential gas buildup in containers. Appendix O of this procedure lists low pH waste solutions as those that are likely to generate gases causing excess pressure within containers.
- Procedure CP2-EP-EP5031, Rev. 1, "Oil and Hazardous Material Spills and Releases," provides direction for responding to releases of hazardous wastes. Section 6.7, "High Risk Drums," of this procedure provides direction for responding to releases of hazardous wastes. This section also provides direction for personnel discovering a bulging drum including the use of Fire Services personnel for puncturing or opening bulging drums. This procedure does not identify hazards to Fire Services personnel who puncture or open a bulging or high-risk drum.
- Procedure KY/EM-96 "Waste Acceptance Criteria for Treatment, Storage, and Disposal Units at the Paducah Gaseous Diffusion Plant," outlines requirements generators must meet prior to transferring waste to PGDP treatment, storage, and disposal units.
- A September 26, 1983 internal memo titled, "Drums in C-746-B Radioactive Warehouse," noted that the integrity of the drums was of concern and recommended repackaging those drums.
- Previous yellow alerts (e.g., as described in Section 2.1.2) identified the embrittlement of polyethylene-lined containers due to strong oxidizers as the cause of the incident.

- A report prepared in July 22, 1991, at the K-25 Site (now ETTP) titled, *Proposed Neutralization/Pre-treatment for Nitric Acid Strip Tank Waste and Other Drummed Lab Wastes Stored in the Vault 4A Facility*, summarized the limitations of polyethylene-lined containers for the long-term storage of strong oxidizing agents.

The paragraphs below present the analysis of the facts pertaining to the policies and procedures.



Tracking and trending is not conducted on lessons learned or occurrences.

LMES Procedure QA-331 implements the Lessons Learned Program that utilizes various levels of alerts (red, yellow, green, and blue). An "uncontained on-site hazardous release requiring cleanup" would justify a red alert and a managerial response. The released waste resulting from the Building C-746-Q drum explosion did not reach the environment, so it was determined to be contained, and a yellow alert was issued. Evidence shows that the waste was not contained within the diked area (secondary containment) since it was found on the walls and ceiling. So one could argue that the spill was uncontained. The definition of "uncontained on-site hazardous release requiring cleanup" should be clarified to indicate whether it applies only to releases that reach the environment or releases not contained by engineered barriers.

Although numerous similar events have occurred and have been documented and reported in various forms, LMES management actions to address the failure of polyethylene liners have been inconsistent. ETTP has taken some steps to mitigate the potential for accidents; however, PGDP continues to store its inventory in their original containers. The Y-12 Plant has similar problems but possibly to a lesser extent. LMES needs to reassess its occurrence reporting and lessons learned systems to ensure that the appropriate level of attention is given based on the risk involved.

LMES must ensure that the appropriate root cause is identified when reporting occurrences. In past occurrence reports the root cause was incorrectly identified. The Y-12 Plant Occurrence Report Y-12 WASTE-1997-0004 incorrectly identified the root cause as a drum overpressurization. A yellow alert (Y-1997-OR-LMESY12-0701) issued as a result of this accident warned against storing organic material and nitric acid in closed containers. However, the root cause of the accident was the failure of the polyethylene liner. Because the root cause was incorrectly identified in the occurrence report, the lessons learned from the accident were invalid.



Care should be taken to correctly identify root causes in occurrence reports.

Tracking and trending is not conducted on lessons learned or occurrences. Although there have been several similar incidents and lessons learned, LMES continued business as usual, issuing lessons learned and occurrence reports. By using tracking and trending information from lessons learned and occurrences, a summary lessons learned or occurrence report could be written. This summary report would consolidate the information from the past events and should require a response.

PMWM-1002 IAD, Rev. 1, is the LMES procedure for managing containers. The procedure does not address when to repackage wastes as opposed to overpacking. The procedure warns of potential gas buildup in containers resulting from chemical reactions of low pH solutions. The procedure does not address the limitations of polyethylene liners for storing low pH solutions.

Procedure CP2-EP-EP5031, Rev. 1, fails to require a hazard analysis prior to puncturing a bulging drum. The procedure also suggests utilizing pressure relief devices but does not specify when or where they are appropriate.

The current waste acceptance criteria at PGDP are in draft. The purpose of the document is to provide guidance to the generator on how to characterize, segregate, and package wastes prior to transfer to

waste management. In its current form, the document does not have restrictions on receipt and storage of strong oxidizing agents.

2.2.2 Roles and Responsibilities

The following sections describe roles and responsibilities for DOE-ORO and LMES organizational elements present at the Paducah Site.

2.2.2.1 DOE-ORO Roles and Responsibilities

The following are the roles and responsibilities for organizational elements concerned with functions related to the accident.

Oak Ridge Operations

DOE-ORO organizational functions are described in the *ORO Organizational Manual*, ORO M 110, Change 2, dated May 15, 1997.

Office of Assistant Manager for Enrichment Facilities (AMEF)

This organization is responsible for the development of plans, procedures, and programs for the direction of DOE-ORO activities implementing DOE programs at PGDP and PORTS, including, but not limited to, management of environmental restoration and waste management activities; management of the OSHA Program; management of facilities not leased to USEC; and associated activities, including safety and health oversight. The above mission is discharged through the Office of AMEF, Paducah Site Office, and Portsmouth Site Office.

Paducah Site Manager

The Paducah Site Manager performs the following functions that relate to this accident:

- Provides day-to-day on-site direction and technical oversight of contractor activities in support of environmental restoration and waste management and capital projects.
- Assures that Government and contractor-executed functions are carried out in compliance



Management responsibility for DOE programs at PGDP and PORTS resides with AMEF.

with DOE Orders and in a manner that protects Government and contractor personnel and the general public against all environmental, health, and safety hazards arising from performance of contract work.

- Implements site environmental restoration programs and activities in coordination with the DOE-ORO Assistant Manager for Environmental Management (AMEM), including remedial investigations, alternative evaluations, remedial designs, and remedial actions.
- Manages DOE waste management activities at PGDP, including waste processing, storage, transportation, disposal, and minimization.
- Oversees DOE contractor compliance with OSHA, the Clean Air Act; the Clean Water Act; National Environmental Policy Act; Comprehensive Environmental Response, Compensation, and Liability Act; RCRA; environmental laws; environmental incident notification and reporting requirements; and radiological control requirements of DOE. Reviews and analyzes compliance audits, appraisals, and unusual occurrence reports; evaluates corrective actions to be taken by the contractor (LMES) in response to findings and deficiencies detected; and verifies that corrective actions have been fully implemented.
- Performs on-site surveillance of DOE activities to assure compliance with DOE and other Federal and state environment, safety, and health requirements.

Environmental Restoration Division (ERD)

The ERD Director exercises management responsibility for the following functions that relate to this accident:

- Manages the DOE-ORO Environmental Restoration Program, including remedial action, transition, and decontamination and decommissioning programs and waste management

programs at PGDP and PORTS.

- Ensures technical consistency among facility environmental restoration activities at DOE-ORO sites.
- Coordinates division activities related to the Oak Ridge Reservation, PGDP, and PORTS environmental restoration activities with the regulatory agencies and the public.
- Ensures that contractor-executed functions are carried out in a manner that protects Federal and contractor personnel and the general public against environmental, health, and safety hazards arising from performance of the contract work.
- Evaluates prime contractors' performance on environmental restoration tasks.

The paragraphs below present the analysis of the facts pertaining to DOE-ORO roles and responsibilities.

The Office of AMEF exercises line responsibility for all DOE functions at PGDP, including environmental and waste management activities; the OSHA Compliance Program; and facilities not leased to USEC and associated activities, including safety and health oversight. Continuity of line responsibility for DOE-ORO oversight of contractor activities in support of environmental restoration programs and projects, waste management programs and projects, and capital projects is not evident.

The Paducah Site Manager exercises management responsibility for day-to-day on-site direction and technical oversight of contractor activities in support of environmental restoration, waste manage-



The Paducah Site Manager is responsible for performing on-site surveillance of DOE activities.

ment, and capital projects. The Paducah Site Manager is also responsible for performing on-site surveillance of DOE activities to assure compliance with DOE and other Federal and state environment, safety, and health requirements. The Paducah Site Manager implements site environmental restora-

tion programs and activities in coordination with the AMEM, including remedial investigations, alternative evaluations, remedial designs, and remedial actions.

Although the Paducah Site Manager is responsible for on-site surveillance of DOE activities and technical oversight of designated projects, there is not a comprehensive assessment program in place to identify threats to facilities and waste operations personnel from exploding drums in Building C-746-Q. There were formal, procedure-based Walkthrough and Surveillance Programs at the Paducah Site Office until mid-1996. At that time, the Paducah Site Office work activities were restructured to a project management format. This was due to initiation of performance-based contracts (incentive task orders) where DOE specifies the scope of work and allows the contractor to determine how the work is done. Each project identifies the environment, safety, and health requirements and expected performance with less formal oversight by DOE on the actual work being performed. The project management structure requires each Project Manager to ensure safety oversight of his/her projects. This can be done by the contractor (Health and Safety Officer), subcontractor, DOE subcontractor, or the DOE Project Manager. DOE interfaces with the project Health and Safety Officer but does not direct the work of individual subcontractors.



The implementation of a comprehensive assessment program of DOE and contractor activities at PGDP is not evident.

From the above information, the Board determined that the implementation of a comprehensive assessment program of DOE and contractor activities at PGDP is not evident. The responsibilities for implementing site environmental restoration programs and activities in coordination with the AMEM is identified as a responsibility for the Paducah Site Manager. The Office of AMEM has the responsi-

bility to manage the overall Environmental Restoration Program. However, an interface document delineating the execution of these responsibilities does not exist.

DOE Facility Representatives and/or Program Managers are responsible for ensuring the adequacy of occurrence reports and approving them. Unlike the Occurrence Reporting and Processing System (ORPS), DOE does not have a formal role in implementing the Lessons Learned Program. DOE-ORO can issue alerts but has not to date. DOE is responsible for the collection of data for the purpose of tracking, trending, analyzing, drawing conclusions, and disseminating results. However, past occurrence reports have not always contained sufficient information, and tracking and trending has not been performed.

2.2.2.2 LMES Roles and Responsibilities

The following are the roles and responsibilities for LMES Facility Managers, LMES Shift Superintendents, and LMES Subject Matter Experts (SMEs) in implementing the Occurrence Reporting and Lessons Learned Programs.

- LMES Facility Managers have direct line responsibility for the operations within a particular building(s). The following are their responsibilities in implementing the Occurrence Reporting and Lessons Learned Programs within their building(s):
 - initiating an occurrence report following an incident;
 - determining direct, contributing, and root causes of the occurrence;
 - identifying corrective actions and drafting lessons learned;
 - searching databases for similar events within their organization;
 - reviewing data in Energy Systems Action Management System (ESAMS) and ORPS to identify lessons learned or good practices from other facilities; and
 - drafting an appropriate alert (red, yellow, green, or blue).

- Shift Superintendents transmit the information from the occurrence report to ORPS.
- The LMES SMEs may be part of line management or may be part of central staff. SMEs review and approve the alert level provided by line management.
- Senior management within LMES sign off on yellow, green, and red alerts.

The paragraphs below present the analysis of the facts pertaining to LMES roles and responsibilities.

The usefulness of information retrieved from ORPS depends upon the accuracy of the information that is in the system. If information is inaccurate, attempts to query the system for similar events will be unsuccessful. For example, attempts to find accidents that involved the failure of polyethylene liners would not locate the Y-12 Plant occurrence or alert because the root cause was misidentified in ORPS (e.g., Y-1997-OR-LMESY12-0701).

ORPS and other databases that support the Occurrence Reporting and Lessons Learned Programs are terminology limited. A query to search for accidents resulting in a “drum explosion” will not identify drum explosions that were input into ORPS as drum ruptures, drum overpressurizations, drum failures, etc. Because there is no standard language, similar accidents may be reported in various ways. It is unreasonable, however, to establish a common, comprehensive language for occurrence reporting or alerts.

Facility Managers are not responsible for identifying similar events that have occurred outside of their building(s), and thus, most do not have access to ORPS. Therefore, Facility Managers are limited in their ability to identify similar accidents and learn from them.

The intent of the Lessons Learned Program is to collect and disseminate positive and negative information with other organizations and sites. However, since no single organization or individual within LMES is responsible for tracking and trending lessons learned, the collection and dissemi-

nation of like events is not performed, and the success of the program is hindered.

2.2.3 LMES Assessment Program

The following are facts of assessment activities performed by LMES at the Paducah Site.

- Assessment activities performed by LMES are described in Procedure PMQA-1050, Rev. 1, “Integrated Management Assessment Program.” The purpose of this program is to provide a system of assessments to identify deficiencies in performance relative to laws, regulations, and DOE Orders and requirements; provide corrective actions for each deficiency; and track corrective actions to closure.
- The assessment activities performed by LMES consist of organization self-assessments, a Performance Evaluation Program, compliance performance measurement system assessment, Facility Excellence Program, readiness reviews, evaluations of Performance Measurement Team implementation, management reviews, occurrence reporting system, performance indicators and trend analysis, lessons learned/alerts, root cause analysis and issues management, compliance with contractual requirements, and management review of assessment reports.
- Schedules for assessments are developed semi-annually, and deficiencies are identified from activities being reviewed. Corrective action plans and schedules are developed to correct identified deficiencies. Corrective actions are tracked until closure and reported to DOE monthly.

The paragraph below presents the analysis of the facts pertaining to the LMES assessment activities.

Deficiencies in the Lessons Learned Program and root cause analysis are identified in Section 2.2.1 of this report. Assessment activities for Building C-746-Q include walkthroughs, technical audits, management assessments, RCRA inspections, compliance audits and surveillances. However,

these assessment activities did not review lessons learned reports, occurrence reports, and other technical reports that identify problems with nitric acid/hazardous wastes stored in polyethylene/steel containers prior to the start of the assessments. As a result of these deficiencies, assessment activities did not detect problems with overpressurized drums in Building C-746-Q until HC-1093 exploded.

2.3 CONTROLS AND ANALYSIS

The subsections to follow provide the barrier and control analysis, change analysis, and causal factor analysis.

2.3.1 Barrier and Control Analysis

Barriers and controls generally can be classified into one of four categories: (1) engineering design, which is the most effective means of eliminating hazards from a work environment; (2) safety devices, which are placed on individual pieces of equipment, around whole processes, or on employees as a secondary protective measure to ensure work safety; (3) warning devices, which are placed on individual pieces of equipment or processes that cannot feasibly be designed to eliminate every hazard; (4) procedural controls, which are written, implemented, and enforced in work environments where additional measures are required to eliminate the effects of an existing or potential hazard that cannot be reduced through design or the use of safety and warning devices.

Three types of barriers were present in Building C-746-Q prior to the accident. Engineering design barriers, safety devices (PPE), and procedural (administrative) controls were present, and they all failed to prevent the accident. However, door locks and radiation protection barriers kept unauthorized personnel from the area where the accident occurred. *Table 2-1* presents a detailed barrier and control analysis.

2.3.2 Change Analysis

Change analysis considers failures in barriers from planned or unplanned changes in a system that

disturb normal operations. *Table 2-2* shows details of the change analysis performed by the Board.

2.3.3 Causal Factor Analysis

The **direct cause** of the accident was the excessive buildup of pressure due to chemical reactions within the container, resulting in an explosion of the container; however, there were also causal factors, i.e., contributing causes and a root cause. **Contributing causes** are causes that, if corrected, would not by themselves have prevented the accident but are important enough to be recognized as needing corrective action to improve the quality of the process. **Root causes** are the fundamental causes and associated corrective actions that, if corrected, would prevent recurrence of an event or adverse action. The causal factor analysis presented in *Table 2-3* uses techniques from Management and Oversight Risk Tree based root cause analysis and the Institute of Nuclear Power Operations's Good Practice OE-907, "Root Cause Analysis."

Table 2-1. Barrier and Control Analysis

Barrier and Control Analysis		
Barrier	Purpose	Performance
Procedure OP-301, "Occurrence Notification and Reporting"	To ensure investigation and identification of the root cause following an occurrence.	Barrier failed because: <ul style="list-style-type: none"> • Not all occurrence reports identify the appropriate root causes. • Tracking and trending were not performed.
Procedure PMWM-1002 IAD, "On-Site Handling and Disposal of Waste Material"	To outline requirements for segregating, collecting, storing, treating, and disposing of hazardous wastes.	Barrier failed because: <ul style="list-style-type: none"> • Did not address limitations on using polyethylene-lined containers for the long-term storage of strong oxidizing agents. • Did not address specific criteria for overpacking vs. repackaging. • Did not adequately address when pressure relief devices are appropriate or allowable.
Waste management control system	To provide controls for segregating, collecting, storing, treating, and disposing of hazardous wastes.	Barrier failed because: <ul style="list-style-type: none"> • There were no approved waste acceptance criteria that provided requirements for waste treatment, storage, or disposal. • Disregarded findings and recommendations from prior events. • Disregarded warnings in PMWM-1002 IAD regarding buildup of gas pressure in waste containers.
Overpack drum HC-1093	To provide storage and containment of nitric acid mixed wastes.	Barrier failed because: <ul style="list-style-type: none"> • Nitric acid degraded the polyethylene liner and reacted with the primary container and the steel drum overpack.
Overpack policy/practice to use 12-mil polyethylene liner for overpacks	To provide containment of primary container of acid mixed wastes.	Barrier failed because: <ul style="list-style-type: none"> • Policy was not followed in late 1986.
Procedure QA-331, "Lessons Learned Program"	To outline roles and responsibilities and provide implementation guidance.	Barrier failed because: <ul style="list-style-type: none"> • Management failed to recognize similarities of past alerts. • Tracking and trending were not performed.
Building C-746-Q concrete floor dikes	To provide containment for hazardous waste spills on the floor of Building C-746-Q.	Barrier failed because: <ul style="list-style-type: none"> • Although this barrier contained the mixed wastes that spilled within the limits of the dikes, the mixed wastes exploded beyond the limits of acid waste storage area B-08.
29 CFR 1910.120 (HAZWOPER) Safety and Health Program	To provide a site-specific safety and health plan to identify, evaluate, and control safety and health hazards to hazardous waste operations.	Barrier failed because: <ul style="list-style-type: none"> • There was not a site-specific safety and health plan or work permit for Building C-746-Q that provided for hazard identification and mitigation for employees exposed to hazards from overpressurized drums.

Table 2-2. Change Analysis

Change or Difference		Analysis	
Planned/Normal	Present	Difference	Analysis
Steel/polyethylene primary containers are utilized for long-term storage of nitric acid/radioactive wastes.	Reliability and integrity of steel/polyethylene primary container questioned in 1983, 1984, and 1991 but continued to be used.	Steel/polyethylene primary containers are not suitable for long-term storage of nitric acid/radioactive wastes.	Failure to determine long-term reliability of containers leads to policy/practice of overpacking nitric acid/radioactive wastes.
85-gal overpack should consist of 12-mil polyethylene liner inside 85-gal steel drum.	Normal policy/practices not followed, and polyethylene liner was not used.	85-gal steel overpack was quickly penetrated by nitric acid when leak developed in primary container.	Polyethylene liner inside steel drum would have extended container life of 85-gal overpack.
Primary container safely contains acid wastes, and there is no gas buildup in containers and overpack.	Primary container leaked acid into 85-gal steel overpack causing a rapid development of gas.	Low pH acid wastes reacted with steel/polyethylene drum and caused gas buildup. Low pH acid wastes reacted with steel/polyethylene drum and caused gas buildup.	Gas buildup from steel/acid reaction is sufficient to cause explosion in 110-gal overpack.
Personnel safety for Building C-746-Q requires hazard identification and mitigation according to 29 CFR 1910.120 (HAZWOPER).	Building C-746-Q is unsafe for personnel engaged in hazardous waste operations due to potential for exploding container.	Potential for explosion of waste containers caused Building C-746-Q to be unsafe for normal activities.	Safety in Building C-746-Q must be enhanced due to potential for container explosion.
Procedure PMWM-1002 IAD warns of gas buildup in waste container requiring installation of approved pressure relief device.	Building C-746-Q waste containers do not have pressure relief devices.	There are no safeguards installed on waste containers to prevent additional explosions.	Potential for waste container explosion in Building C-746-Q not mitigated.
Lessons Learned Program provides for disseminating, identifying, and utilizing positive and negative operating experiences.	Lessons learned not implemented and not utilized where previous nitric acid/radioactive waste drum storage is concerned.	LMES management did not utilize lessons learned information to repackage nitric acid/radioactive wastes in compatible containers.	The accident could have been prevented by using previous information from lessons learned.
Occurrences require timely identification, categorization, notification, evaluation, corrections, and reporting.	Occurrence reporting system improperly categorized the occurrence and did not provide timely notification.	Categorization of event was updated to unusual, and notification did not meet the 2-hour time limit.	Corrections to occurrence report were required.

Table 2-3. Causal Factor Analysis

Causal Factor Analysis	
Contributing Causes	Discussion
Procedures	Warnings in existing procedures regarding the potential for gas buildup in waste containers were not heeded.
Waste acceptance criteria	There was no approved waste acceptance criteria document. The waste acceptance criteria do not place restrictions on the acceptance of strong oxidizers or address the limitations of polyethylene for long-term storage of strong oxidizers.
Overpack policy or practice	Policies and practices failed to provide guidance on when it is appropriate to repackage as opposed to overpacking a suspect container.
Occurrence reports	Occurrence reports do not always identify the appropriate root causes in past events. There is no single organization or individual responsible for tracking or trending information from the occurrence reporting system.
Lessons learned	There was a failure to properly implement the Lessons Learned Program, and the findings and recommendations in an LMES report (<i>Proposed Neutralization/Pre-treatment for Nitric Acid Strip Tank Waste and Other Drummed Lab Wastes Stored in the Vault 4A Facility</i> , dated September 13, 1991) and a yellow alert (Y-PAD-91-0002, "Polyethylene Reagent Container Failure") were disregarded. There is no single organization or individual responsible for tracking or trending information from the lessons learned system.
Personnel safety	There was a failure to provide hazard analysis and mitigation for exploding drums for hazardous waste operations personnel working in Building C-746-Q (i.e., there was no safety and health plan). A required safety and health plan, including safety and health permits, must conform to 29 CFR, Part 1910.120 (HAZWOPER).
DOE oversight	DOE failed to perform adequate oversight of environmental and waste management activities at PGDP and did not identify hazards from exploding waste drums.
Root Cause	Discussion
Failure of management control systems	LMES management failed to recognize the significance and/or act appropriately on information regarding the incompatibility between acid wastes and waste containers.

3.0 CONCLUSIONS AND JUDGMENTS OF NEED

This section of the report identifies the conclusions and judgments of need, as determined by the Board, by using the accident analysis methods described in Section 2.3. Conclusions of the Board consider significant facts and pertinent analytical results. Judgments of need are managerial and procedural controls believed necessary to prevent

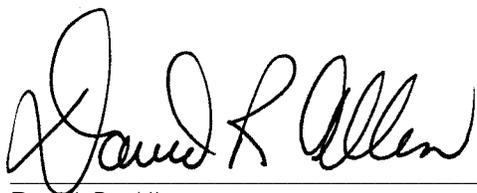
or mitigate the probability or severity of a recurrence. They flow from the conclusions and causal factors and are directed at guiding managers in developing follow-up actions. *Table 3-1* identifies the conclusions and corresponding judgments of need identified by the Board.

Table 3-1. Conclusions and Judgments of Need

Conclusions and Judgments of Need	
Conclusions	Judgments of Need
LMES has lessons learned procedures that could have, if adequately implemented, prevented this accident.	LMES management needs to: <ul style="list-style-type: none"> • Adequately implement a Lessons Learned Program. • Assess the criteria for assigning alert levels. • Ensure the accuracy of occurrence reports and ensure the appropriate root cause(s) have been identified.
No documentation exists restricting the storage of strong oxidizing agents.	LMES needs to proceduralize a process for neutralizing corrosive wastes prior to long-term storage. Restrictions need to be placed on the acceptance of wastes that pose unique hazards when stored. The Waste Management Division needs to modify its waste acceptance criteria (KY/EM-96) accordingly for treatment, storage, and disposal units.
PGDP container management procedures fail to provide guidance for repackaging wastes as opposed to overpacking.	LMES needs to: <ul style="list-style-type: none"> • Develop guidance to repackage waste as opposed to overpacking the container when appropriate. • Modify the waste handling procedure (PMWM-1002 IAD) to clarify the limitations of polyethylene-lined containers for storage of strong oxidizing agents.
There are no provisions for personnel safety from exploding drums in Building C-746-Q.	LMES needs to develop a safety and health plan for HAZWOPER personnel in Building C-746-Q that conforms to 29 CFR 1910.120 (HAZWOPER).
Neither DOE nor LMES adequately tracks or trends information from occurrence reports or lessons learned.	DOE-ORO needs to track and trend information from the occurrence reporting and lessons learned systems, as defined by ORO M 110, Change 2, dated May 15, 1997. LMES needs to track and trend information from the occurrence reporting and lessons learned systems.
DOE does not adequately perform oversight.	DOE needs to: <ul style="list-style-type: none"> • Develop a comprehensive oversight program for PGDP. • Ensure occurrence report information is accurate and complete.

BOARD SIGNATURES

4.0 BOARD SIGNATURES



David R. Allen
DOE Accident Investigation Board Chairperson
U.S. Department of Energy, Oak Ridge Operations

11-6-97

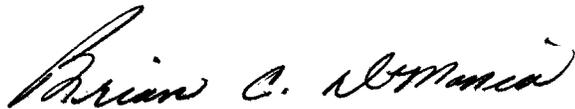
Date



James S. Campbell
DOE Accident Investigation Board Member
U.S. Department of Energy, Oak Ridge Operations

11/6/97

Date



Brian C. DeMonia
DOE Accident Investigation Board Member
U.S. Department of Energy, Oak Ridge Operations

11-6-97

Date



William M. (Mike) Arendale
DOE Accident Investigation Board Member
U.S. Department of Energy, Oak Ridge Operations

11-6-97

Date

LISTING OF BOARD MEMBERS, ADVISORS, AND STAFF

5.0 LISTING OF BOARD MEMBERS, ADVISORS, AND STAFF

Board Chairperson	David R. Allen, DOE-ORO
Board Member	James S. Campbell, DOE-ORO
Board Member	Brian C. DeMonia, DOE-ORO
Board Member	William M. (Mike) Arendale, DOE-ORO
Advisor	Gregory A. Bazzell, DOE Paducah Site Office
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APPENDIX A

APPOINTMENT

CORRESPONDENCE

FOR TYPE B

ACCIDENT

INVESTIGATION

memorandum

DATE: September 16, 1997

REPLY TO

ATTN OF: SE-32:Mullins

SUBJECT: **TYPE B INVESTIGATION - RUPTURED WASTE DRUM, C-746-Q RCRA
WASTE STORAGE FACILITY, LOCKHEED MARTIN ENERGY SYSTEMS, INC.,
PADUCAH, KENTUCKY**

TO: David R. Allen, Technical Support Division, SE-32

You are hereby appointed Chairman of the Investigation Board to investigate the subject incident which was discovered on September 15, 1997. Although the incident does not meet investigation requirements as defined by DOE Order 225.1, the similarity to other incidents within Lockheed Martin Energy Systems, Inc. (LMES), at Paducah and Oak Ridge cause me great concern.

You are to perform a Type B investigation of this incident and to prepare an investigation report. The report shall conform to the requirements detailed in DOE Order 225.1 and DOE G 225.1-1, Implementation Guide for Use with DOE 225.1, Accident Investigations. The scope of the investigation is to include, but is not limited to, analyzing causal factors and identifying root causes which resulted in the incident, and determining judgments of need to prevent recurrence. The Board will also focus on management roles and responsibilities, application of lessons learned from similar type accidents within the Department (especially those within LMES), and work planning, practices and procedures. If additional resources are required to assist you in completing this task, please let me know and it will be provided. You and members of the Board are relieved of your other duties until this assignment is completed.

The following employees have been appointed to serve as members of the Board:

Brian C. DeMonia, Waste Management and Technology Development, Member
James S. Campbell, Operations Division, Trained Investigator
W. Mike Arendale, Nuclear Safety Division, Member

The Board will provide my office and Robert Poe, Assistant Manager for Environment, Safety, and Quality, with periodic reports on the status of the investigation and not include any findings or arrive at any premature conclusions until an analysis of all the causal factors have been completed.

Draft copies of the report should be provided to LMES and appropriate ORO staff for factual accuracy review.

The final draft of the investigation report should be provided to me by October 20, 1997. Discussions of the investigation and copies of the draft report will be controlled until I authorize release of the final report.



James C. Hall
Manager

cc

T. J. O'Toole, EH-1, HQ, 7A-097/FORS
A. L. Alm, EM-1, HQ, 5A-014/FORS
G. S. Podonsky, EH-4, HQ, C-303/GIN
D. Vernon, EH-2 1, HQ/GIN
Jimmy C. Massey, LMES, 761 Veterans Ave., Kevil, KY 42053
S. A. Polston, LMUS, MS-100, Paducah
Jimmie Hodges, EF-22, Paducah
Steve Wyatt, M-4, OR
R. W. Poe, SE-30, OR
R. R. Nelson, EW-90, OR
J. W. Parks, EF-20, OR
W. T. Cooper, EH-24, OR Steve Wyatt, M-4, OR



Department of Energy

Oak Ridge Operations Office
P.O. Box 2001
Oak Ridge, Tennessee 37831-

September 16, 1997

Dr. Robert I. Van Hook
President
Lockheed Martin Energy Systems, Inc.
P.O. Box 2009
Oak Ridge, TN 37831-8001

Dear Dr. Van Hook:

TYPE B INVESTIGATION - RUPTURED WASTE DRUM, C-746-Q RCRA WASTE STORAGE FACILITY, LOCKHEED MARTIN ENERGY SYSTEMS, INC., PADUCAH, KENTUCKY

As a result of the subject incident which was discovered on September 15, 1997, I am directing that a Type B investigation be conducted. Although the incident does not meet investigation requirements as defined by DOE Order 225.1, the similarity to other incidents within Lockheed Martin Energy Systems, Inc. (LMES), at Paducah and Oak Ridge cause me great concern.

The investigation will be performed by the following individuals:

David R. Allen, Technical Support Division, Chairman
Brian C. DeMonia, Waste Management and Technology Development, Member
James S. Campbell, Operations Division, Trained Investigator
W. Mike Arendale, Nuclear Safety Division, Member

The scope of the Board's investigation will include, but is not limited to, analyzing causal factors and identifying root causes which resulted in the incident, and determining judgments of need to prevent recurrence. The investigation will be conducted in accordance with DOE Order 225.1. The Board will also focus on management roles and responsibilities, application of lessons learned from similar type accidents within the Department (especially those within LMES), and work planning, practices, and procedures.

Draft copies of the investigation report will be provided for factual accuracy review. The final draft report of the investigation should be provided to my office by October 20, 1997.

Sincerely,



James C. Hall
Manager

cc

T. J. O'Toole, EH-1, HQ, 7A-097/FORS
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